

Starter motor control system

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ABSTRACT

Starter motor converts electrical energy through a battery into mechanical rotating energy. These motors work under heavy load. They produce big power in a short time and in a small volume. Starter motor conveys its rotating energy with a pinion to the flywheel. For initiating internal combustion engine, the rotating moment of starter motors should be requested being greater. The starter motor must be rotating the flywheel at a minimum starting speed. It must also continue support rotation during initial combustion to maintain momentum until the engine can sustain operation. The starter motor turns for approximately 3 seconds during each starting attempt. In each attempt the starter motor gear bounces out and meshes with the flywheel attached to the engine crankshaft. During the compression cycle of each cylinder, the starter motor torque is high, resulting in higher force on the starter gear teeth. Because of the lack of over current protection, the traditional starter control through solenoid easily causes short circuit and burns out starter. So the starter motor and its components are subjected to either mechanical fault like wear, fractures of moving parts or electrical faults like short interrupted circuit and contact resistance increase etc. This paper focuses on the need of electronic control unit based starting system with some practical observations made and also state of charge of battery is also discussed.

Keywords:

Micro-controller, starter motor, battery, alternator

1. COMMON PROBLEMS:

1.1. BATTERY FAULT:

Automobile engine starting needs extremely high current, in the range of 600 Amps peak for 250 ms, then a 150 A to 300A sine wave at a reasonably stable voltage for 0.5 seconds to 3 seconds. Starter efficiency increases with the higher deliverable voltage. Batteries needed for these applications should be the capable of operation at the temperatures ranging from -20°C to 50°C. In battery fault, the battery cannot provide enough current in order to turn the flywheel. In this Condition the battery is fully discharged or there is problem on charging system and therefore revolution of the motor will be too low.

1.2. STARTER MOTOR FAULTS

Starting of SI engines at low temperatures is easier than CI engines due to sparking systems in the combustion chamber and the fuel properties. By using the conventional lubricating oils, fuels, etc., SI engines can easily be started by using more volatile fuel having 10% evaporation temperature at about 40°C. Starting of diesel engine creates problems of cold starting at lowest temperatures. While studying problems of cold starting, they were observed that four operating factors influence the diesel engine starting: (I) design of engine, (ii) lubricating oil properties, fuels and coolant, (iii) battery conditions and starter motor, and (IV) use of starting aids. Hence, cold starting of IC engines under the sub-zero temperature conditions are a delicate operation. A little carelessness can damage the whole engine, but if proper precautions are taken and right type of starting aid, fuel, coolant, lubricating oil, etc. are used, then a summer like start can be achieved.

In the case of starter motors, the load of the machine is an engine, with widely varying load torque, which is dependent on the motor condition, external environment, and multiple resonances. If any fault occurred on starter motor, peak current during cranking will increase. The mostly observed faults on starter motor and starter system are; brush fault, battery fault, open circuit fault (broken connection cables, loses battery pole etc.), armature fault, field (excitation) winding' fault and short circuit fault. Because of improper starter mounting, switching and lack of maintenance etc., teeth of the starter pinion and flywheel ring gear may not mesh properly and even impact each other. Due to improper mesh or violent impacts, it can bring on to unstable, high transient forces and torques and moments during starting, and therefore troubles or failures such as gear teeth flake off, meshing harness, tightly meshing, armature failure, drive end housing fracture etc., are common in application after a certain period of service time. As the starter gear applies force, a moment comes where contact between the starter and a flywheel gear is lost, followed by a knock when contact is re-established. This mechanical transient translates into speed and torque transients and, subsequently, into a short transient of the stator current.

2. ALTERNATOR & CHARGING SYSTEM CHECKS:

2.1. ALTERNATOR CHARGING OUTPUT:

The alternator in vehicles is the heart of the charging system. It supplies all the power needed to keep the battery fully charged and to run everything electrically in the vehicle. The alternator is put up on the engine and is belt-driven off the crankshaft pulley by a snake belt or v-belt. The alternator produces alternate current (AC), which is having changed to direct current (DC) by a six diode rectifier, which is usually placed inside the back of the unit. Diodes only pass current in one direction, which they converted from AC current to DC. Three positive diodes operate the positive side of the AC sine wave, while three negative diodes operate the negative side.

The charging of alternator output increases in proportion to the electrical load on the charging system and engine speed. Output is low at idle and increases also with RPM. Maximum output is typically attained at speeds above 2,500 RPM.

2.2. ALTERNATOR VOLTAGE REGULATION

Charging output of the alternator is managed by a voltage regulator which may be attached inside or back of the alternator (internally regulated), or somewhere else below the hood (externally regulated). On most upcoming vehicles, the powertrain control module (PCM) regulates charging output.

On older vehicles, the voltage regulator is electro-mechanical and used magnetic contacts to operate the charging of alternator output. Since 1980s, most common voltage regulators are solid-state electronic and utilize transistors to operate charging output.

The actual output voltage induced by the alternator will differ depending on temperature and load, but typically about 1-1/2 to 2 volts will be higher than battery voltage. At idle, charging systems will induce 13.8 volts to 14.3 volts with no lights or no accessories ON (some may charge at little higher voltage depending on type of battery, engine RPM, the battery's state of charge and temperature). This can be measured by connecting the positive (+) and negative (-) test pins of a voltmeter to the battery posts while the engine is running.

2.3. ALTERNATOR CHARGING VOLTAGE

Most alternators are charging properly that should induce a voltage of about 13.8 volts to 14.2 volts at idle condition with accessories and lights OFF. For example, Many Asian vehicles have higher charging voltages of about 15 volts.

When the engine is started first, the charging voltage should increase rapidly to about 2 volts above the base battery voltage, then become smaller, leveling out at the fixed voltage.

The exact charging voltage will differ according to the battery's charging state, the loads on the vehicle's electrical system, and temperature. The lower temperature will higher the charging voltage, and the higher temperature will lower the charging voltage. The "normal" charging voltage on a typical application may be 13.9 volts to 15.1 volts at 77 degrees Fahrenheit. But at 20 degrees Fahrenheit below zero, the charging voltage may jump as high from 14.9 volts to 15.8 volts in short period of time. On a hot engine on the hot days, the normal charging voltage might fall to 13.5 volts to 14.3 volts.

2.4. ALTERNATOR AMPERAGE OUTPUT

In addition to checking the alternator's voltage output, you also want to check out its current or amperage output. Amperage is strength of an electrical current when the alternator generates at a specified voltage and speed. Not long ago, an 80 amp alternator was regarded as a high output unit. Latest model alternators produce 120 to 155 amps or more. Current output raises with engine speed, from around 20 to 50 amps at idle up to unit's maximum output at 2,500 RPM or higher (refer to a service manual for the exact charging output specifications for any desired vehicle).

Charging output can be evaluated with an inductive amp probe clamped around BAT (B+) wire that connects to an alternator. It can also be measured on the alternator bench tester in an auto parts store.

Alternator power ratings can also be said in Watts (voltage time's ampere). The alternators in western countries, vehicles are rated in watts only. The most important point here is that the new alternator which is a replacement of the original has the same power rating (in amps or watts). So the charging system can give the same power output as before. In fact, on some particular applications upgrading alternator by replacing for a higher output, may be recommended if the vehicle has a repeated alternator failures, or the vehicle has an aftermarket sound system which consumes more power and the electrical accessories consumes heavy power which may result in repeated failures.

3. PROBLEM DESCRIPTION:

The problem identified is "Basically in engines, diesel engine need more effort for starting" for this reason there are some of the cases discussed. The following discussion tell about, the usual mistakes of a driver doing while engine is not started and how it is going to affect the starting system. Another common problem is "weak compression" is also discussed.

CASE 1: (Lack of compression)

If the air and fuel is not compressed properly, the combustion process will not work like it should.

Lack of compression might occur for these reasons:

- Piston rings are worn (allowing air/fuel to leak past the piston during compression stroke).
- The intake or exhaust valves are not sealed properly, it results in allowing a leak during compression stroke.
- If there is a hole in the cylinder also affects the compression stroke.

The most common problem "hole" in a cylinder appears where the top of the cylinder (*known as the cylinder head*) connected to the cylinder. Generally, the cylinder and the cylinder head are bolt together with a thin **gasket** pressed between them to ensure a good sealing. If the gasket collapsed, small holes will occur between the cylinder and the cylinder head, and these holes create leakages.

CASE 2: (during repeated starting)

- Starter runs 15000 RPM at Armature Shaft.
- By means of Reduction gear the RPM comes down to 3000 which increase the torque.
- When starter engages with Fly wheel it turns the Engine 300 RPM since the Pinion of the starter and Fly wheel are 1: 10 ratio approximately.
- Since the Driver operates more number of Time the starter burn.

CASE 3:(prolonged application of starter switch)

When we apply the starter switch for long time heavy current is allowed to flow on the copper coil of starter motor.

When a current of I amperes passes through a circuit of resistance R ohms for a period of time (t) seconds, then the heat generated is given by the equation.

$$H=I^2Rt \text{ joules}$$

The above equation is known as the joule's law of heating. It states that produced heat is proportional to,

- Square of the current (I).
- Resistance of the circuit (R)
- The time (t) during which the current flows through the circuit.

Heat produced in calories can be expressed as

$$H=I^2Rt/4.18 \text{ calories}$$

(1 calorie=4.18 joule)

Increase in duration as well as current causes the starter burn out.

CASE 4: (pressing the starter switch after engine starts)

We observed that while traffic, people came to forget their engine was started already but they again press the starter switch. That will results in starter pinion breakage

CASE 5: (Battery state)

Condition of the battery plays an important role in starting system, if the battery is not in "good" condition it is not have enough potential to ensure good and quick start.

It depends on,

- Previous Usage of the battery
- Alternator condition
- Condition of the electrolyte.

4. APPROACH:

By observing these situations we had an approach to solve these problems it ensures the safety and better operation of starter motor and battery.

1. Cranking for 3 seconds:

By limiting the starter motor to run only for 3 seconds we limits the duration of current flow in the armature coil and we can able to reduce the heat generation by limiting the amount of current flow and duration of current flow.

2. Crank for 3 times:

Instead of cranking repeatedly, we reduce the repetition of cranking to 3 times also after 3 seconds of every cranking starter motor kept in "idle" for 2 seconds, this duration is helpful for restoring the power of battery for next cranking.

With this, we attempt to minimise the power spent on cranking so battery state is safeguarded.

3. Alternator output:

In order to find whether the engine is started or no, a standard reference value is required. Normally, we identified the engine start condition with sense of sound came from the engine and so we utilised the alternator output voltage as reference for engine start. Usually, idling of engine at this condition alternator output voltage ranges from 13volt - 14.5volt. We adopted 13volt as reference value and that implies "Engine is started".

Below 13volt of alternator output, it is taken that engine was not started and we adopt a small period of time after cranking and alternator reaches 13volt and above thus engine was started.

4. State of the battery:

If the battery state is not good the potential of the battery drained in faster rate, we are restrict the potential do not fall below 8V.so that feedback is taken from the battery in order to cut the supply of starter motor to protect the battery.

REQUIREMENTS:

- PIC CONTROLLER CHIP.
- PIC EVALUATION BOARD.
- PULL DOWN RESISTOR.-10KOHM
- LCD DISPLAY 16x2.
- SIMPLE DC MOTOR.
- 12 VOLT RELAY

5. RESULTS AND DISCUSSIONS

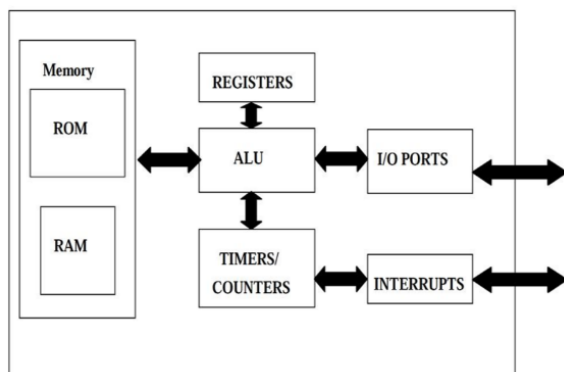


Figure 5.1 Block Diagram

Using PROTEUS V7.7SP2.we had simulated our program. Under varying condition of the following,

- Driver command
- Condition of battery
- Alternator output

Response of starter motor is checked

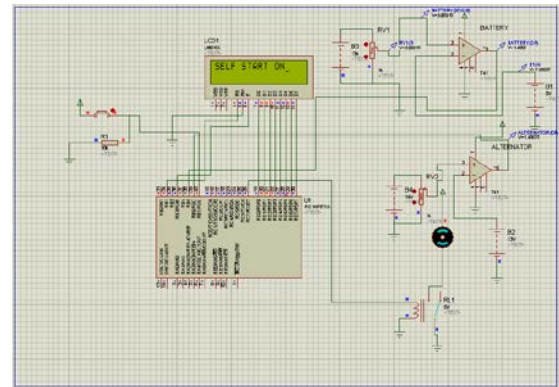


Figure 5.2: Self-start ON

Figure shows,

Initially driver is giving an input to the system by pressing starter switch.so that processes initiated as instructed in the program which is fed into PIC16F877A MICROCONTROLLER

In order to visualize the process are being done. We use LCD16*2 which is added in the program coding as given in chapter 3 methodology, under program code.

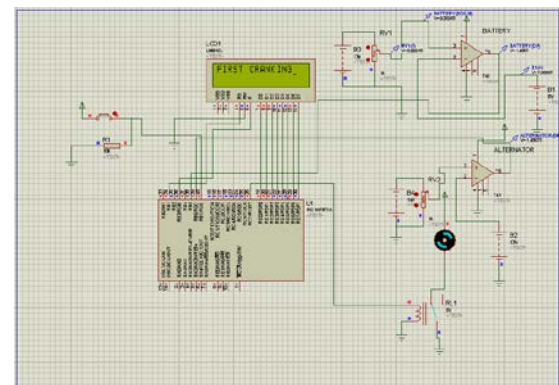


Figure 5.3:First cranking

Figure shows.

The initial process is a command given by the driver is read by MICROCONTROLLER and it initiates the cranking.

Starter motor draws heavy current from battery in order to generate heavy torque to turn the flywheel the amount current drawn falls gradually within a small interval of time because of increase in back emf at end of starter motor armature the back emf is generated (based on faraday's law of electromagnetic induction). Because of the rotation of armature in the permanent magnet field.

It is like, the output of starter motor rotation causes increase in potential at the starter motor end.

Before cranking, potential at battery end is high and potential at starter motor end is nearly zero .within a fraction of second, the potential of starter motor end increases so that current drawn by the starter motor from

the battery decreases gradually. at this period of time the engine is cranked (in seconds).

The healthy battery remains in good condition. That is, it withstands its potential after cranking, if the engine is started means, alternator produces steady output voltage by utilizing engine's idle speed which will vary 13 To 14.5 volt

If these situation are obtained then the LCD shows "engine start".

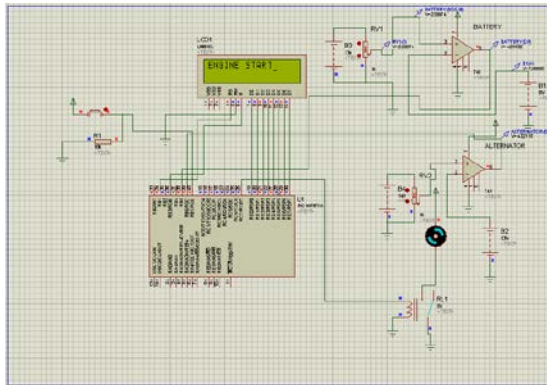


Figure 5.4: Conditions satisfied

Figure shows,

The condition of battery and alternator voltage output plays key role in controlling the operation of starter motor. While cranking the potential of battery slightly decrease which will not fall below 8volt at average rated conditions.

In case the condition of battery is not good due to any reasons (insufficient charging alternator fault leakage in battery, electrolyte specific gravity fall).the potential falls below 8 volt which is not desired for battery operation and it affects the life of battery

So using relay cut off the supply to the starter motor in order to protect the battery. Immediately cranking or stopped and wait for 3 seconds for next cranking

This process is repeated for 3 times when the battery potential falls below 8 volt. LCD shows "engine not started"

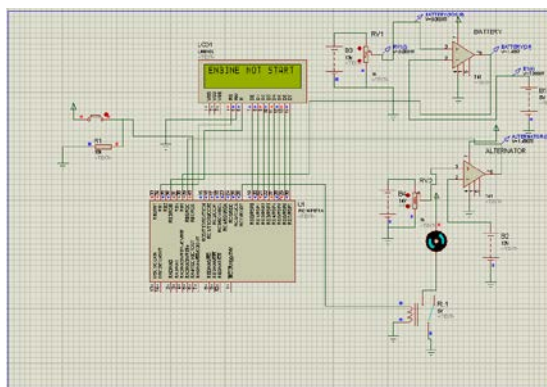


Figure 5.5: Conditions not satisfied

Figure shows,

In some place usually in traffic, the driver forgets his/her engine is running, drive again pressing starter switch which leads to starter motor pinion teeth breakage and also affects the gear profile of flywheel

In order to eliminate this situation, PIC MICROCONTROLLER receives input signal from battery and alternator. Starting from battery ON until battery OFF.

If the driver crank the engine while the engine is running in idling speed, microcontroller omits that driver's signal as simulated below

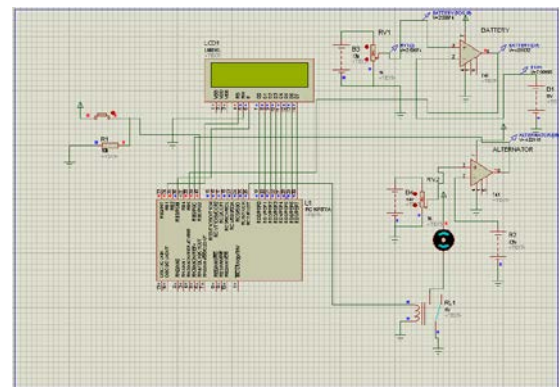


Figure 5.6: Omitted crank

Figure shows,

In order to verify the engine is started, we utilize the information received from battery and alternator from ON To OFF of the vehicle, by checking the following conditions made available in microcontroller comparing with actual outputs from battery and alternator terminals.

They are,

- Battery potential is greater than 8 volt (>8v)
- Alternator output voltage is greater than 13 volt (>13v)

If the above conditions are not satisfied the process proceeds further after the first cranking, the process follows the instructions written in the MICROCONTROLLER as second, third cranking until those two conditions are satisfied.

6. ADVANTAGE:

- Increasing Battery Life.
- While the Engine is Running, Turning ON the starter motor is omitted automatically.
- Increasing service life of Starter Motor.

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